ZOOMABLE SPOT MODULE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention relates to the lighting arts. It is especially applicable to the packaging of light emitting diodes (LED's) to form a spot light, flashlight, or other lamp type that produces a collimated or partially collimated beam, and will be described with particular reference thereto. However, the invention will also find application in packaging of LED's, semiconductor lasers, halogen bulbs, and other light emitting elements for spot lighting, flood lighting, and other optical applications.

DISCUSSION OF THE ART

Spot light lamps emit a collimated or partially collimated beam of light (e.g., a conical beam), and are employed in room lighting, hand-held flashlights, theater spot lighting, and other applications. Examples of such lamps include the MR-series halogen spotlights which incorporate an essentially non-directional halogen light bulb arranged within a directional reflector, such as a parabolic reflector. The MR-series halogen spotlights are commercially available with or without a front lens, and typically include electrical connectors disposed behind the parabolic reflector, i.e., outside of the range of the directed beam. The reflector, optionally in cooperation with a front lens, effectuates collimation of the halogen light bulb output to produce the collimated or conical light beam. The MR-series spotlights are available in a range of sizes, wattages, color temperatures, and beam angles. However, the MR-series spot ights do not include adjustable beams.

The Maglite® flashlight is a prior art device that has an adjustable spot beam. An incandescent light bulb is arranged inside an essentially parabolic reflector. This device effectuates a variable beam angle ranging from

a narrow spot beam to a wide, "flood" beam, by including a rotating actuator for moving the reflector axially with respect to the incandescent bulb. This arrangement suffers from significant beam non-uniformity when the light source is strongly defocused. Under conditions of extreme defocusing, the Maglite® flashlight beam exhibits a black spot at the beam's center.

Lamps which utilize one or more LED's as the source of light are becoming more attractive as the light output intensities of commercial LED's steadily increase over time due to design, materials, and manufacturing improvements. Advantageously for spot module applications, commercial LED's typically have a lensing effect produced by the epoxy encapsulant that is usually employed to seal the LED chip from the environment. Hence, these commercial LED's are already somewhat directional, and this directionality can be enhanced using an external lens. Additionally, LED's that emit white light of reasonably high spectral quality are now available. In spite of continuing improvements in LED light output, at present an individual LED is typically insufficiently bright for most lighting applications. Nonetheless, due to the small size of LED's, this intensity limitation can be obviated through the use of a plurality of closely packed LED's that cooperate to produce sufficient light.

Application of LED's to spotlighting applications, and especially to spotlighting applications in which the LED-based lamp is contemplated as a retrofit for replacing an existing lamp that employs another lighting technology (e.g., a retrofit for replacing an MR-series halogen lamp) is complicated by the use of multiple LED's as the light source. The spatially distributed nature of an LED source array greatly reduces the effectiveness of conventional parabolic reflectors which are designed to collimate and direct light emanating from a point source, such as light generated by a halogen or incandescent bulb filament. Furthermore, a front lens of the type optionally included in an MR-series halogen spot lamp is ill-suited for collimating light from a plurality of LED's, because most of the LED's are not positioned on the optical axis of the lens. Thus, the optical systems of existing spot lamps, both with and without variable beam angle, are relatively ineffective when used in conjunction with LED light sources.

The present invention contemplates an improved light source or lamp that overcomes the above-mentioned limitations and others.

BRIEF SUMMARY OF THE INVENTION

In accordance with one embodiment of the present invention, a lamp is disclosed. An LED module includes at least one LED arranged on a substrate. An optical system includes at least one lens in optical communication with the LED module. A zoom apparatus selectively adjusts the relative axial separation of the optical system and the LED module.

In accordance with another embodiment of the present invention, a lamp is disclosed. An LED module includes a plurality of LED's for generating a lamp beam. An adaptive optical system selectively adjusts the angular spread of the lamp beam.

In accordance with yet another embodiment of the present invention, a lamp is disclosed. A light source optically interacts with an optical system having at least one lens in optical communication with the light source. A zoom apparatus selectively adjusts the relative axial separation of the optical system and the light source.

Numerous advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating a preferred embodiment and are not to be construed as limiting the invention.

FIGURE **1** shows an isometric view of a zoomable spot lamp that suitably practices an embodiment of the invention.

FIGURE **2** shows a schematic cross-sectional view of a zoomable spot lamp that suitably practices an embodiment of the invention, the lamp being shown as adjusted to produce a wide-angle flood beam.

FIGURE **3** shows a schematic cross-sectional view of the lamp of FIGURE **2**, adjusted to produce a narrow-angle spot beam.

FIGURE **4** shows a front view of the lamp of FIGURE **2**, looking directly into the beam, with dotted lines indicating the hidden sleeves of the zoom apparatus and the interlocking mechanism.

FIGURE **5** shows a schematic cross-sectional view of the lamp of FIGURE **2** in a first mounting configuration.

FIGURE **6** shows a schematic cross-sectional view of the lamp of FIGURE **2** in a second mounting configuration.

FIGURE **7** shows a schematic cross-sectional view of a zoomable spot lamp that suitably practices another embodiment of the invention, the lamp being shown as adjusted to produce a wide-angle flood beam.

FIGURE **8A** shows a front view of the lamp of FIGURE **7**, looking directly into the beam, with the zoom apparatus rotated at a reference position, herein designated as 0°, between the first and second sleeves.

FIGURE **8B** shows a front view of the lamp of FIGURE **7**, looking directly into the beam, with the second sleeve rotated 120° compared with its reference orientation of FIGURE **8A**.

FIGURE **8C** shows a front view of the lamp of FIGURE **7**, looking directly into the beam, with the second sleeve rotated 240° compared with its reference orientation of FIGURE **8A**.

FIGURE **8D** shows a front view of the lamp of FIGURE **7**, looking directly into the beam, with the second sleeve rotated slightly more than 240° compared with its reference orientation of FIGURE **8A**.

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIGURE **1**, a lamp that suitably practices an embodiment of the invention is described. A lamp or light source **10** includes a

plurality of light emitting diodes (LED's) **12** arranged on a base or substrate **14**, the combination of which forms an LED module **16**. A plurality of lenses **18** are arranged in conjunction with the LED's **12**, such that each LED **12** lies on the optical axis of one of the lenses **18**. The lenses **18** effectuate a collimation of the light emitted by the LED's **12**, so that the lamp output is a collimated or conical beam having a desired angle of divergence. Preferably, the LED's **12** are positioned closely to the lenses **18** to maximize the light captured. For this reason, the lenses **18** should be fast lenses, i.e., should have a low f number. These preferred lens optical properties are not readily obtainable using conventional lenses. Accordingly, fresnel lenses are advantageously used for the lenses **18** to provide very low f number behavior in a reasonably sized lens.

In the illustrated embodiment of FIGURE **1**, there is a one-to-one correspondence between lenses **18** and LED's **12**. That is, each LED **12** is associated with a single lens **18**. This in turn allows each LED **12** to lie on the optical axis of its corresponding lens **18**, which maximizes the optical efficiency of the combination. In other words, the spatial pattern of the lenses **18** corresponds with the spatial pattern of the LED's **12**.

The lenses **18** are arranged on a zoom apparatus **20** which together with the lenses form an adaptive optical system **22**. The optical system **22** is relatively adjustable with respect the LED module **16** to enable a selectable distance separation along the optical axis between the lenses **18** and the LED's **12**.

Because the lamp **10** is intended for lighting applications, the LED's **12** preferably emit light at high intensities. This entails electrically driving the LED's **12** at relatively high currents, e.g., as high as a few hundred milliamperes per LED **12**. Because LED light emission is very temperature-sensitive, the heat dissipated in the LED's **12** as a consequence of the high driving currents is advantageously removed by a heat sink **24** which is thermally connected with the substrate **14**.

With reference now to FIGURES **2** through **4**, a lamp **30** that suitably practices an embodiment of the invention in which the zoom apparatus

operates on a mechanical sliding principle is described. LED's **32** are arranged on a substrate **34** forming an LED module **36**. A plurality of lenses **38**, which are preferably Fresnel lenses, are arranged in correspondence with the LED's **32**, with each LED **32** lying on the optical axis of an associated lens **38**. A sliding zoom apparatus **40** includes two slidably interconnecting elements or sleeves **42**, **44**. The LED module **36** is arranged on or in the first sleeve **42** in a fixed manner. The lenses **38** are arranged on or in the second sleeve **44**, also in a fixed manner. It will be appreciated that zoom apparatus **40** of the lamp **30** effectuates beam width adjustment through the relative motion of the sleeves **42**, **44**.

The configuration of the zoom apparatus **40** shown in FIGURE **2** corresponds to a minimum relative separation between the LED's **32** and the lenses **38**. This configuration produces a wide beam, i.e., a conical beam with a wide angle of divergence, sometimes called a flood light.

The configuration of the zoom apparatus **40** shown in FIGURE **3** corresponds to a maximum relative separation between the LED's **32** and the lenses **38**. This configuration produces a narrow beam, i.e., a conical beam with a small angle of divergence, sometimes called a spotlight.

A sliding zoom apparatus can optionally effectuate continuous zoom adjustment (not shown). For continuous zoom adjustment, the sleeves should be of sufficiently close relative tolerances so that the frictional force between the two sleeves **42**, **44** inhibits unintended sliding slippage therebetween.

Alternatively, as shown in the illustrated embodiment of FIGURES **2** and **3**, the zoom apparatus **40** is an indexed zoom apparatus. A projection or stop **46**, which can be a single projection, a plurality of projections, or an annular projection, extends from the first sleeve **42** and is selectably moved into one of five recesses or stop positions **48**, which can be annular grooves, holes, or the like. The projection(s) **46** and the recesses **48** are mutually adapted to enable relative movement of the sleeves **42**, **44** to selectably move the stop **46** to a selected stop position **48**. The projections or stop **46** and the recesses or stop

positions **48** cooperate to bias the zoom apparatus into certain pre-selected axial spacings or stop positions. It will be appreciated that such an index system tends to reduce slippage between the two sleeves **42**, **44** versus a similar continuous zoom adjustment which relies upon frictional force to prevent slippage. Of course, the index system of FIGURES **2** and **3** is exemplary only, and many variations thereof are contemplated, such as placing the stop onto the first sleeve and the recesses onto the second sleeve, using other than five stop positions, etc.

With reference to FIGURE **4**, in addition to the zoom indexing system exemplarily effectuated by projection(s) **46** and recesses **48**, the lamp **30** also includes an advantageous interlocking mechanism including a linear projection **50** aligned along the sliding direction of the sliding zoom apparatus **40** and extending inwardly from the second sleeve **44** toward the first sleeve **42**, and a corresponding linear depression **52** that receives the linear projection **50**. This interlocking mechanism prevents relative rotation between the first and second sleeves **42**, **44** so that the LED's **32** are maintained centered on the optical axes of the lenses **38**.

With reference to FIGURES **2** and **3**, the lamp **30** also includes one or more electrical conduits **54** through which wires or other electrical conductors (not shown) connect the LED's to an associated power supply (not shown). Although an exemplary single conduit **54** is shown, numerous variations are contemplated, such as separate conduits for each LED **32**.

In addition, electrical components such as a printed circuit board that electrically connects the LED's **32** and has optional driving electronics operatively arranged thereupon, metallized connections, an associated battery or other electrical power supply, etc., are also contemplated (components not shown). It will be recognized that such electrical components are well known to those skilled in the art.

With reference to FIGURE **5**, a mounting configuration **60** for the lamp **30** of FIGURES **2** through **4** is described. In the mounting configuration **60**, the inner sleeve **42** remains fixed relative to a mounting element **62**, while

the sliding movement of the outer sleeve **44** effectuates the zoom adjustment. The mounting element **62** could, for example, be the approximately cylindrical body of a hand flashlight that contains associated batteries to power the lamp **30**, in which case movement of the outer sleeve **44** is effectuated manually by the user. Alternatively, for a theater stage spotlight mounting configuration, the movement of sleeve **44** could be mechanized. It will be appreciated that the mounting configuration **60** is rather simple to construct because the adjustable outer sleeve **44** is accessible.

With reference to FIGURE **6**, another mounting configuration **70** for the lamp **30** of FIGURES **2** through **4** is described. In the mounting configuration **70**, the outer sleeve **44** remains fixed relative to a mounting element **72**, while movement of the inner sleeve **42** effectuates the zoom adjustment. In this case, the inner sleeve **42** is relatively inaccessible from outside the mounting configuration **70**, and so in the embodiment of FIGURE **6** one or more posts **74** are rigidly affixed to the inner sleeve **42** and pass through passthroughs **76** in the mounting element **72** to provide handles or shafts by which the inner sleeve **42** is slidably adjusted to effectuate the zoom. The mounting configuration **70** is therefore more complex versus the mounting configuration **60** of FIGURE **5**. However, the mounting configuration **70** has the advantage of fully containing the lamp **30** within the mounting element **72** so that a lighting device that employs the configuration **70** has definite and fixed outside dimensions. The one or more posts **74** are also easily adapted to connect with a motor (not shown) to effectuate a mechanized zoom adjustment.

With reference to FIGURE **7**, a lamp **80** that suitably practices another embodiment of the invention in which the zoom apparatus operates on a mechanical rotation principle is described. LED's **82** are arranged on a substrate **84** forming an LED module **86**. A plurality of lenses **88**, which are preferably Fresnel lenses, are arranged in the same pattern as the LED's **82**. The rotating zoom apparatus **90** includes two threadedly interconnecting elements or sleeves **92**, **94**. The LED module **86** is arranged on or in the first sleeve **92** in a fixed manner. The lenses **88** are arranged on or in the second

sleeve **94**, also in a fixed manner. Thus, by relatively screwing the first and second sleeves **92**, **94** into or out of each other using the cooperating threads **96**, **98** disposed on the outside of the first sleeve **92** and the inside of the second sleeve **94**, respectively, the relative axial separation of the LED's **82** and the lenses **88** is adjusted. The first sleeve **92** preferably includes one or more electrical conduits **104** which are analogous to the conduit or conduits **54** of the embodiment of FIGURE **2**.

Although the LED's **82** and the lenses **88** are arranged in the same spatial pattern, it will be recognized that the rotating motion in general results in a misalignment of the LED's **82** off the optical axes of the lenses **88**. However, for certain relative rotational orientations of the sleeves **92**, **94**, the two patterns align, as shown in FIGURE **8A**. The relative rotational orientation shown in FIGURE **8A** is herein designated as 0° and serves as a reference orientation. Furthermore, a specific LED $\mathbf{82_0}$, and a specific lens $\mathbf{88_0}$, are shown in bold in FIGURE **8A** and will be tracked during zoom adjustment using FIGURES **8B** and **8C** in the discussion which follows.

With reference to FIGURE **8B**, the reference orientation has been changed by rotating the second sleeve **94** counter-clockwise by 120°. Two changes result from the 120° rotation. First, the axial separation of the LED's **82** and the lenses **88** changes by an amount related to the spacing of the threads **96**, **98** due to the screwing action. Second, the lens $\mathbf{88_0}$ is no longer axially aligned with the LED $\mathbf{82_0}$, but rather now axially aligns with another LED as seen in FIGURE **8B**.

With reference to FIGURE **8C**, the second sleeve **94** has been rotated counter-clockwise by another 120° (240° total rotation versus FIGURE **8A**). The axial separation of the LED's **82** and the lenses **88** is again changed by an amount related to the spacing of the threads **96**, **98**, and the lens $\mathbf{88_0}$ axially aligns with yet another LED as seen in FIGURE **8C**. Although not illustrated as a separate figure, it will be recognized that a third counter-clockwise rotation of 120° would bring the total rotation versus FIGURE **8A** up to 360°, i.e. one complete rotation, and would re-produce the pattern alignment

shown in FIGURE **8A**, but with a change in axial spacing between the LED's **82** and the lenses **88** corresponding to the spacing of the threads **96**, **98**.

In one aspect of the embodiment, the threads **96**, **98** have thread joints, indented stops or another mechanism (not shown) to bias the zoom apparatus **90** into indexed positions such as those shown in FIGURES **8A, 8B,** and **8C** wherein the lens **88** pattern aligns with the LED **82** pattern. It will be recognized that if the lens **88** pattern and the LED **82** pattern each have an n-fold rotational symmetry, then separation of the rotational stop positions by integer multiples of 360°/n enables stop positions for which each LED **82** is axially aligned with one of the plurality of lenses **88**. In the exemplary embodiment shown in FIGURES **8A, 8B** and **8C**, the patterns have six-fold rotational symmetry (n=6), and the stop positions are separated by 2×(360°/n) = 120° rotations.

In another aspect of the embodiment, the rotation of the zoom apparatus **90** can also be continuous with no index biasing. In this case the frictional interaction between the threads **96**, **98** should be sufficient to counteract slippage of the zoom apparatus **90**.

FIGURE **8D** shows a relative rotational orientation of the LED **82** pattern and the lenses **88** pattern wherein the LED's **82** are not axially aligned with the lenses **88**, but rather are relatively positioned slightly off-axis. It will be recognized that a relative pattern orientation such as that shown in FIGURE **8D** can be obtained either with or without index biasing. Such a slightly off-axis relative orientation produces defocusing which can provide further freedom for adjusting the light beam properties. In FIGURE **8D**, the second sleeve **94** has been rotated to an angle **A** relative to the reference rotational orientation of FIGURE **8A**, where the angle **A** is slightly greater than the 240° orientation that would produce pattern alignment.

The invention has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations

insofar as they come within the scope of the appended claims or the equivalents thereof.